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Goran Bakalar
E-mail: goran.bakalar@xnet.hr
Bonum Mare Consulting LLC, 148 Young Ave, Cocoa Beach, USA
MH Systems Inc., San Diego, CA, USA
International Maritime Technology Consultancy, Put Radosevca 52, 21000 Split, Croatia
Myriam Beatriz Baggini
E-mail: abaggini@hotmail.com
Bonum Mare Consulting LLC, 148 Young Ave, Cocoa Beach, FL, USA

Bridge officers' operational experiences with electronic chart display and information systems on ships

Abstract

In this paper, authors suggest an improvement in the electronic chart display and information system handling. Electronic nautical charts provide significant benefits to maritime navigation as a real time navigation system and all updates are important. This paper analyses the electronic chart use experiences on board ships. A questionnaire and survey were used so as to ascertain and corroborate the existing problems with corrections and maintenance of electronic charts on ships, and reliability of the systems was calculated. The survey results have shown that ship's officers had serious problems with ECDIS systems which were difficult to solve during ship's operation. A survey was done which showed that a significant percentage of the surveyed bridge officers and captains had problems with ECDIS system operation, such as operation stoppage due to different reasons. They did not always report failures of these systems while having continued to operate ECDIS. The reliability of those systems was also calculated and it resulted 0.916 or 91.6%. Compared to results of previous similar researches done by other scientists, the results of this research show an improvement in the ECDIS handling. It was concluded that a proper action was needed toward finding the solution to the future chart corrections procedure through remote monitoring and maintenance. The study results emphasized that taking action was necessary in the interest of safety protection on ships, with particular attention to be paid to better safety of navigation, of life, and of potential environmental pollution due to this type of information system failures. The results obtained by this study represent a good starting point for future researches in the field.

Key words: operational experiences, survey, reliability, electronic chart, ECDIS

1. Introduction

The modern microprocessor technology and display systems make it entirely feasible for many of the deck and bridge functions to be automated which were previously performed manually on ships. There are many benefits to be derived from automation; the question today is not whether a function can be automated, but whether it should be in the way as it is, due to various human factor issues [14]. It is highly questionable whether the total system safety is always enhanced by allocating functions to automatic devices rather than human operators, and there is some reason to believe that automation may have already passed its optimum point. This is an age-old question in the human factors profession. This paper identifies a few critical problem areas, and offers a broad design solution. The problem of operational experience and impact of diffidence to ECDIS systems are still unknown. Some automation-related accidents and incidents are discussed here as examples of human factor problems in automation [36]. Due to recent incidents involving navigational problems, there is a growing concern about automation and its potential effects on the performance of bridge duties [17]. However, little is known about the nature and causes of the problems arising from the bridge-automation interaction. Operational experiences very significantly contribute to learning more about crew members' behavior on ships [13]. In this article, results are reported of two studies that provide converging, complementary data on ECDIS end-users' difficulties with the understanding and operating one of the bridge automation IT systems, the electronic chart display and information systems.

The ECDIS system is a computer based navigation system that complies with IMO (International Maritime Organization) regulations and can be used as an alternative to paper navigation charts. Integrating a variety of real time information, ECDIS is an automated decision aid, capable of continuously determining vessel's position in relation to the land, charted objects, navigation aids and unseen hazards. This system displays the information from ENC (electronic navigation charts) and other navigational sensors such as the radar, GPS (Global Positioning System), depth sounder, and AIS (Automatic Identification System) for identifying and locating vessels by electronical data exchange in the local traffic. The ECDIS system is important for nowadays navigation since it continuously provides ship's position, increases navigational safety, and generates alarms when the vessel is in the proximity of navigational hazards.

The overall aim of this study was to develop processes to reduce the negative impact that ship operators have experienced in relation to navigation safety, safety of life and the environmental pollution.

In June 2010, improvements in standards of ships' automated navigation contained in "The Manila amendments to the STCW (Standards of Training, Certification and Watchkeeping for Seafarers) Convention and Code" [26], were agreed. As advised by the IMO (International Maritime Organization), the important changes included new requirements relating to training in the ECDIS handling and operation. All deck officers assigned to serve on vessels equipped with navigational electronic chart systems

must receive the approved training in the use of ECDIS [25] [35] and a specific ECDIS traning course.

On ships, at the beginning of the voyage, as well as at any watch exchange, the officers should review the voyage plan and agree on the selected pre-setting of functions, alarms and indicators to be used on the ECDIS [22] [23]. The data included in the ECDIS are sometimes temporary hydrographyc data such as exchanged depths, shallows, cables in temporary use, dredgings in ports, etc [2]. Certain scientists have analyzed tides data in the ECDIS [8] and other scientists have compared mariners' reactions in a simulator in order to collect reactions and recommendations based on their complete experience in ECDIS [33].

Due to many external impact factors, experiences from real life on ships are more acceptable for scientific analyses. All navigational charts in use in any kind of transportation need to be corrected periodically. The Electronic Navigational Chart (ENC) cells require updating to include details published in the paper chart Notices to Mariners. These come in two forms: Chart Correcting Notice to Mariners (NTM) and Temporary and Preliminary Notice to Mariners (T&P NTM) [1]. A bridge officer, usually the second officer, is assigned as a responsible officer to receive ECDIS corrections and to enter periodical corrections in navigational electronic charts on ships. Corrections, received via Weekly Updates in a compact disc (CD), or downloaded weekly from a recognised electronic chart supplier's data, are done by inserting the CD into the ECDIS computer and by following the procedure from the instruction manual.

Some corrections are done manually, after an operator (second officer) enters the chart system. Those corrections are T&P (Temporary and Preliminary). Any uncorrected chart data appearing on the electronic chart may cause confusion to the navigator and this is obviously a dangerous condition for the vessel.

Experiences concerning supply issues are also important for a proper IT system operation on ships. The supply chain for any of software and hardware spare parts was the aim of a study where the authors indicated negative relationship between the supply chain management and information system practices [6]. For that purpose, a supplier relationship management should be assigned that is not always in acceptable form depending on certain circumstances [7]. Main parts of information systems on navigation bridges are not always available in the first port the ship is to call. Sofisticated electronic navigational tools, such as radar, radar antenna, dynamic positionning IT systems, GPS, AIS (Automatic Information System), etc., need an extra follow-up management system to avoid potential problems due to warranty expiry causes. Remote maintenance systems have lately developed up to an acceptable level to follow up and predict problems with such an equipment [34]. The aim of this study was to identify any improper or wrongful electronic chart operation caused by bridge officers, failures of that kind of information systems, maintenance problems, and any other problems observed by using ECDIS systems.

2. Materials and methods

Materials in this research are different ECDIS systems, their operational condition, human operators and their operational experience. Methods used in the research comprise a questionnaire, a survey and interviews, and a reliability study.

2.1. Operational experiences

The research in this paper aids in understanding how important it is to learn more about IT system experiences from crewmembers [11]. Certain scientists have analyzed experiences of other operators in other vehicles and industries such as pilots asked to describe specific incidents [36]. Results of two other researches reported improper handling of ECDIS regarding wrong route inputs or other improper handling [4] [28] [29] [30].

In this paper, incidents due to ECDIS operation on ships were not reported by surveyees. Operational experiences with ECDIS systems were surveyed and results obtained. In this study, operational experiences were analyzed with the aim to contribute to the protection of safety of navigation, of ships, of the environment and natural world, and to prevention of pollution. The co-insistency, maintenance and the efficiency of the systems were shown as being the problem as there are no systems for manual chart correction operations from the shore.

Operational experiences are methodically exposed through surveys. The survey raises considerable doubts as to the reliability of quick answers to research questions, whether of a quantitative or qualitative nature [19]. A questionnaire is a research instrument and the basic scientific method of gathering information from respondents. The discovery of reflexive progression in interviewing is very important for research [31]. This study provides survey findings from a sample of 69 experienced ship captains and bridge officers, out of whom 51 attended maritime courses and 18 come from the maritime crewing agency. Respondents' profile is shown in Figure 1.

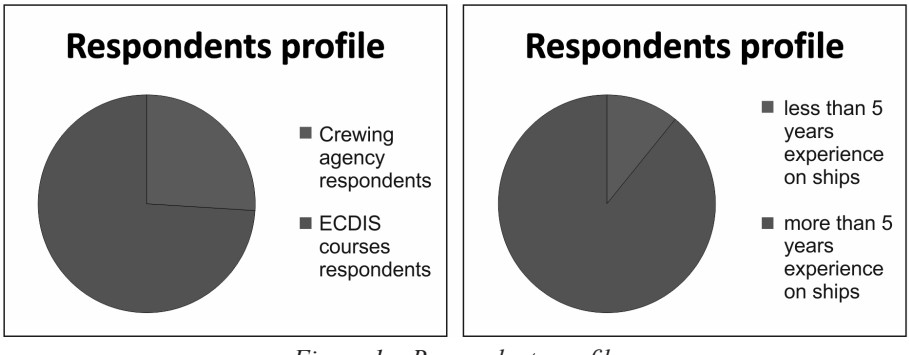

Figure 1 – Respondents profile

Four attendees from the courses have worked on board ships four years and all of them were experienced second officers. Other surveyees from the courses have worked on ships for more than five years in the capacity of chief officers and captains. These courses were taught in Split, Sibenik and Rijeka, Croatia, at the Nautical School, and the attendees were interviewed in the period from 20/12/2014 to 1/3/2015. Out of the 18 ship officers and captains who were surveyed at the maritime crewing agency, two of them were bridge officers with four years' experience and other officers, who were the subject of the survey, confirmed that they had served on board ships for more than five years. They were surveyed and interviewed in the same time period, from 20/12/2014 to 01/03/2015.

Interviews were carried out after the survey research data had been collected. An on-board experience questionnaire was made for the purpose of this research and a summary of survey results is given and explained further in this paper. A simple exploratory questionnaire was created with four questions.

The questionnaire

The questionnaire was made up of the following:
Circle one answer only.

1) How many years have you worked on board ships?
a) one year
b) three years
c) five years
d) more than five years

2) I work on ships as a:
a) bridge officer
b) captain

3) There is an ECDIS installed on the ship that I work on:
a) Yes
b) No

4) There were some functional problems encountered while the ECDIS system was in operation:
a) Yes
b) No

2.2. Reliability study

Performance reliability of certain electronic chart display and information systems on board ships has its own indicators which ought to be observed, followed and analysed over a longer period of system exploitation. Reliability is the ability of the system for operational work without interruption **[32]**. There are lot of essential questions of what should be considered related to use of ECDIS on ships **[20] [24] [37]**. In this paper the aim was to consider operational experiences and ECDIS operators' opinions. The comparison of survey results and of reliability calculation has contributed to the consideration of real operation with ECDIS on ships. The reliability calculation results can prove how important operational experiences are. The following calculation proves that ships' crew members should have some problems with ECDIS operation on ships. Those problems should be considered and a follow- up system or check-up solution would be proposed and agreed. Some remote system solutions were suggested in other important ships' systems. The reliability of those systems was also calculated and it results acceptable **[18]**. The time of use is an indication of performance but not a direct measure of operation in accordance with standards **[12]**.

3. Results

3.1. Results of the survey

Three course attendees (out of the 51 surveyed) responded affirmatively to questions 3 and 4 of the questionnaire. Within the maritime crewing agency, one experienced officer responded affirmatively to questions 3 and 4. Four ship captains among those surveyed confirmed during their interviewing that they had encountered problems while operating the ECDIS and two of them had heard about such problems only long after the occurrence.

The problems that these officers and captains referred to were related with systems' use and updating. Their sensors would freeze the operation of a certain electronic chart display and information system due to the manual update of temporary (T&P) updates. As reported by an officer, there was no specific reason for the system to freeze and its freezing was not caused by an improper update of the system unit. After restarting the system, the problem would disappear, and the T&P correction as well. He didn't try to do that single T&P correction again.

During the interview, only two bridge officers that were surveyed said they were serving on board a ship with an installed system with two individual ECDIS systems. According to them, there had been no problems encountered such as freezing or malfunctioning.

According to a captain who was interviewed for the survey, the motherboard of a system had never caused a problem to one particular ship, but it went out of order

on just the same day that the warranty expired. The computer components included in motherboard are: the microprocessor, coprocessors, memory, bios system, expansion slot and interconnecting circuity. The interviewed captain didn't know in detail which part of the motherboard broke up on the occasion. They had no serious consequences, owing to the paper charts the ship was in possession of, as well. They got a new spare part at the first port of call.

Another ECDIS system was not able to operate due to dirty filters and overheating problems. These problems were also referred to by another bridge officer who was on the ship with an installed ECDIS. The filters were too dusty and the system was not operating properly, probably due to poor ventilation and cooling. Complete results are shown in Figure 2 and in Table 1.

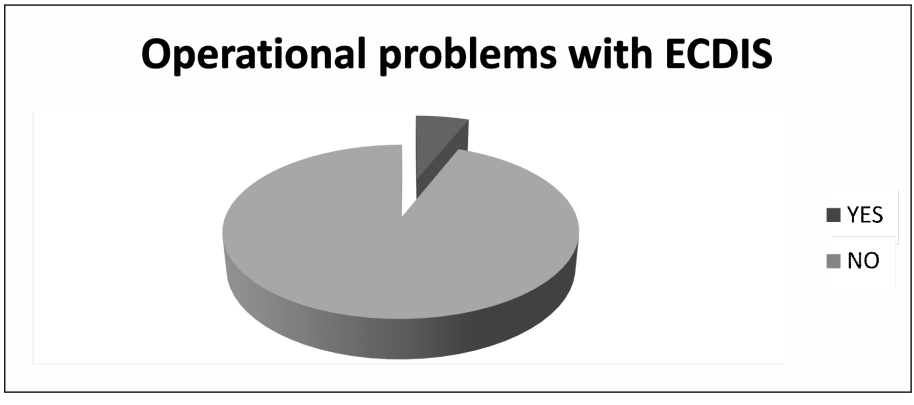

Figure 2 - Results of question 4
(regarding experienced functional problems with ECDIS)

All of the interviewed officers stated that they had passed the educational process in the past. They stated that in the future the temporary manual updates should be done in shore offices and sent to ships as usual updates. It could be as often as needed. One of the improper functions of the ECDIS surveyed in this research should be eliminated in that way.

The courses they were attending while surveyed were taught by one of the authors of this research. The complete survey results can be found in Table 1.

Table 1
Survey results

	ECDIS on board	No ECDIS on board	Operational problems	Total sample surveyed	Total % with operational problems
Surveyed Crew members attending courses	49	2	3	51	5.88 %
Surveyed Crew members at the ship manning agency	16	2	1	18	5.55 %
Total	65	4	4	69	5.8%

Research regarding this problem should continue in the future so as to observe how survey results vary over time. Trend analysis reports would allow the survey response data to be charted over time and to be published in scientific journals.

ECDIS systems are not always in optimal operational condition and ships' crew members often by-pass or ignore the problems occurred. They don't always report them and the issue may be similarly compared with the problem of by-passing automatic oil discharge content monitors in the past [12]. This is an unacceptable facet of the paperless (no paper charts on board) implementation. This could be, among other hazards, an environmental hazard as well, and environmental hazards need to be managed or, in this case, monitored through Environmental Management Systems (EMS) initiated by EPA [21].

Reliability of ECDIS systems should be increased by implemented duplication of such systems (two individual independent ECDIS systems) on a ship. The number of paperless ECDIS vessels will increase. Proper actions should be taken on different educational, practical and preventing levels [5]. Electronic navigation systems cannot be guaranteed to be 100 % failsafe, and there must be some form of back-up redundancy in case of ECDIS failure. Certain scientists have proposed a model of three ECDIS devices, where the third one is produced by a different manufacturer. That would significantly improve maritime safety [38]. The following example in this research is a reliability calculation for two ECDIS units considering the most optional value of the malfunction index.

3.2. Results of reliability study

The malfunction index or maintenance failure of ECDIS systems which cannot be diagnosed and automatically eliminated for these types of devices ranges from $\lambda = 0.5$ to $\lambda = 0.2$ [9]. λ can only be determined from the on board ship operational history

which is at present unavailable for any of ECDIS systems. The mean value of the malfunction index was the most optional value in this calculation and it was taken for all systems in common. If the mean is taken as being $\lambda = 0.35$ for each of the serially attached subsystems and this value is included in the equation of reliability for 1000 hours of work, we can obtain a reliability value for each of the two ECDIS computing systems individually, where one of them is redundant:

$$R\,(t) = e^{-\lambda t} = e^{-0.35} = 0.704688 \quad (1)$$

The total reliability R(u) of the whole computing subsystem as part of an ECDIS system on board ships which consists of two units, one of which is software redundant, is:

$$R\,(u) = R(t)\,(1-\lambda t) = 0.916097 \quad (2)$$

As such, the reliability of this subsystem has been proven acceptable according to the reliability analysis results for the computing system, which is a subsystem of an ECDIS system on board ships. The computing subsystem reliability with the possibility of using the redundant software is 0.916 or 91.6%. Results of this study are in accordance with survey results and should lead to complete sustainability in the future. Nevertheless, among other reasons, the result of the use of electronic charts depends on the level of user's qualification [27]. Compared to similar researches, results in this research are better than those concerning the survey within a research carried out in 2012., where 17.5 % of respondents didn't agree that ECDIS improves the situation awareness [3]. It was concluded that respondents had some objections related to the reliability and complexity of the systems and readiness of operators. Respondents mentioned that ECDIS decrease navigational skills and make bridge officers over relaxed and lazy. They also reported the hardware reliability problems were experienced, but they didn't specify the problem they referred to.

In this article, the research results point more to exact problems, so it has been concluded that bridge officers have troubles with T&P corrections, expiration of hardware units, and over heated systems due to dusty dirty vents.

One of the solutions to these problems could be additional training in this area. This was suggested for the maintenance of fire fighting equipment on ships, after the operational experience in that field had been obtained **[10]**.

Remote monitoring could be a good suggestion as well **[15] [16]**, but that would be a future step in automation on board ships. T & P corrections could be controlled by few bridge officers: responsible officers for updates, Chief Officer, and Captain. In that way, all of them should follow these updates and would be aware of each notice for T&P corrections. *Freezing* of the systems should be registered automatically with some relevant office or the company office the ship belongs to.

4. Conclusion

In this paper, posssibilities have been considered for improvement of ships' navigation and problems have been reveiled concerning the use of ECDIS on ships. According to survey results, four bridge officers, out of 69 surveyed, experienced operational problems with the use of ECDIS. The survey results indicate that ECDIS systems may become faulty and shut down when operation sensors indicate improper function of the sub-systems. ECDIS was found to have problems with dirty vents, cooling, manual T&P updates and passed-out main motherboard. However, based on the study results, it is concluded that there may be a need to reconsider the basic design criteria in terms of operation principles of ECDIS, operation and management of the systems from the updates and automation monitoring aspect. 5.8 % of the surveyed bridge officers and captains stated that ECDIS systems were not always in optimal operational condition and ships' crew members often bypassed or ignored the problems occurred. The research in this paper contributes to the understanding of how important it is to learn more of ECDIS experiences from crewmembers, since the survey of operational experiences from ships has proven that more attention would be needed for the manual update and the maintenance of ECDIS systems. The total calculated reliability of the entire computing subsystem as part of a particular ECDIS on board ships, which consists of two units of which one is software redundant, was 0.916 or 91.6%. This means that for 8.4% of the operational time, any of the mentioned systems could be in failure or under repair. This is a significant risk for the operation of ECDIS systems. Crew members' overwork should be absolutely avoided in this matter. The results of this research are a warning to relevant stakeholders in the maritime industry. If the system does not operate well, or not at all, the systems become unmanageable and out of control. This could be, among other hazards, an environmental hazard as well, and environmental hazards need to be managed through environmental management systems. One of the possibilities would be a mechanism to monitor the systems operation continually from land offices. An automatic update system should be provided and sensors should report malfunctions through internet communication connections immediately after any questionable or doubtful performance of a system occurs.

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Goran Bakalar, Myriam Beatriz Baggini

Iskustva brodskih časnika u korištenju elektroničkog prikazivača pomorskih karata s informacijskim sustavom na brodu

Sažetak

Autori u ovom članku predlažu poboljšanje u rukovanju sustavom elektroničkih nautičkih karata. Elektroničke navigacijske karte pružaju značajnu korist pomorskoj navigaciji kao pravodobni navigacijski sustav te su sva ažuriranja neophodna. Za otkrivanje problema u radu s ECDIS sustavima na brodovima, u ovom istraživanju, korištene su istraživačke metode anketa i intervjua, a pouzdanost tih sustava je potvrđena matematički. Rezultati anketa su pokazali da članovi brodskih posada imaju ozbiljnih problema s ECDIS sustavima u ažuriranju ili održavanju i te probleme teško mogu rješavati za vrijeme brodskih operacija. Numerički su rezultati anketa pokazali da je značajan postotak anketiranih brodskih časnika imao probleme u radu s ECDIS sustavima zbog različitih razloga. Oni nisu uvijek izvješćivali o nekim greškama koje bi se dogodile u radu ECDIS sustava i nastavljali su daljnju uporabu i rad ECDIS-om. Rezultat izračuna pouzdanosti ECDIS sustava je 91.6 %. što pokazuje da je rezultat vrlo blizu rezultata koji se postigao kroz ankete. Rezultati analiza u ovom članku pomažu u razumijevanju važnosti nadgledanja pripreme i sigurnosti plovljenja na brodovima kroz prikupljanje i analizu iskustava članova brodskih posada jer je to, uz poboljšanje sigurnosti navigacije i očuvanja ljudskih života, indirektno važno i u interesu očuvanja okoliša sprječavanjem mogućnosti polucije mora. Zaključeno je da je potrebna pravodobna i pravilna reakcija na rezultate istraživanja i to uporabom daljinskog upravljana nekim korekcijama karata kao i daljinskim autonomnim automatskim nadgledanjem. Rezultat ovog istraživanja je dobar temelj za buduća istraživanja u ovom području.

Ključne riječi: operativno iskustvo, istraživanje, pouzdanost, ECDIS, elektroničke karte.